09/980750
Rec'd PCT/PTO 02 NOV 2001

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Method for Disintegrating and Granulating Slags and Device for Carrying out said Method

The invention relates to a method for disintegrating and granulating slags, in which the molten slag is ejected into a granulation chamber by the aid of a propulsion jet, and a device for carrying out said method.

For the disintegration and granulation of slags it has already been known to charge liquid slags into a slag tundish and discharge the same into a granulation chamber by the aid of a propulsion jet. In that case, the liquid slag was usually discharged into the granulation chamber by the aid of vapor or high-pressure water and atomized when emitted into the granulation chamber, rapid cooling having been effected within the granulation chamber, for instance by the feeding of high-pressure water or the introduction of hydrocarbons. Due to the rheological properties of liquid slags, such slags had to be heated to relatively high temperatures, and in order to obtain an accordingly finely atomized jet also limiting conditions as to the basicity of the slag would have had to be taken into account if a sufficiently fine distribution and hence a sufficiently fine disintegration without subsequent grinding had been sought. An optimized slag composition aimed at as fine a disintegration and granulation as possible, thus, necessarily calls for a compromise in respect to possible slag compositions unless extremely high slag temperatures will be chosen. High slag temperatures, in turn, involve a high wear of the refractory lining of the slag tundish.

In order to obtain a more rapid division of such liquid slags in a consecutively arranged granulation space, it has already been proposed to inject gases into the slag in order to thereby saturate the slag bath with gases. As a rule, inert gases were used for that purpose, with oxygen usually being applicable only to the extent that is required to ensure that a completely oxidized slag will be obtained, which eliminates the risk of undesired explosions in the subsequent supply of high-pressure water to the liquid slag.

The invention aims to provide a method of the initially defined kind, by which it is feasible to vary the composition of the slag and, in particular, the basicity of the slag within wide limits without loosing the advantages of a rapid disintegration and a rapid granulation of slags while, at the same time, providing the opportunity to safeguard the relatively high temperatures required for the rheology of the outgoing slag in a particularly economic and simple manner without involving an increased wear of refractory materials in the slag tundish. Furthermore, the invention aims to enable disintegration and granulation with small-structured devices in a manner that subsequent grinding may be omitted by immediately obtaining a sufficiently fine grain size distribution of the solidified particles.

To solve this object, the method according to the invention essentially consists in that gases, in particular air or oxygen, are introduced into the molten slag to form a foamed slag, that the temperature of the foamed slag is raised to a temperature of above 1350°C, in particular 1420° to 1680°C, by the aid of fuels such as, e.g., coal introduced into the foamed slag, and that the foamed slag is ejected into a granulation chamber. By deliberately forming a foamed slag, the specific weight of the slag is, at first, considerably lowered and reduced, in particular, to approximately 1/10 of the original specific weight of the compact slag melt. When forming such a foamed slag, closed-pore structures with bubble sizes having diameters in the millimeter range will result, whereby such foamed slags can be produced at little expenditure by the suitable introduction of shearing forces such as, for instance, the blowing in of gases through porous flushing blocks as well as the observance of critical temperature ranges as a function of the basicity of the slag. What is essential is the attainment of temperatures above 1350°C and, in particular, between 1420° and 1680°C, such temperatures being readily obtainable in the interior of foamed slags due to the structural properties of foamed slags while, at the same time, enabling the building up of a

temperature gradient towards the edge regions of the foamed slag volume. The temperature required in such foamed slags can be maintained by introducing solid fuels into the foamed slag, which, together with the oxygen blown in, will burn in the interior of the foamed slag while forming said foamed slag, thus simultaneously ensuring said high melting temperatures. In such a foamed slag the desired slag composition may be adjusted in a particularly simple manner and solid additives such as, for instance, CaO, Al_2O_3 and SiO_2 may be added to adjust the slag basicity in the foamed slag to values of preferably 0.8 to 1.3. It is, thus, feasible to build up the desired slag chemistry simultaneously with the desired temperature of the melt bath in the foamed slag, and all this in a particularly economic manner using cost-effective fuels such as cheap coal. A possibly elevated sulfur content of such cheap coals will be bound immediately and directly into the slag, said foamed slag constituting a sort of flameless burner by which also the exhaust gas temperatures may be adjusted in the desired manner. Since the exhaust gas forming is completely dedusted already in the foamed slag with possible dust being slagged *in situ* and also fuel sulfur being bound into the slag due to the basicity of the slag, a highly pure exhaust gas is formed at once, which may, for instance, be conducted directly to the buckets of a gas turbine.

By ejecting such a foamed slag having the desired composition and the desired temperature, into a granulation chamber, a substantially simpler and finer micro-granulation will be obtained than with compact slag melts. The slag is present in the foamed slag melt already in a pre-disintegrated state such that substantially finer particles will form during subsequent rapid cooling. In principle, cooling may be effected in any conventional manner by conducting the foamed slag directly into a conventional water bath, onto a plate-type cooling conveyor or over a centrifugal wheel. According to the invention, it is, however, preferably proceeded in a manner that the foamed slag is ejected by vapor and impacted with high-pressure water in countercurrent. To this end, vapor having a temperature of between 200° and 1200°C and a pressure

of between 5 and 15 bars is advantageously used to eject the foamed slag, high-pressure water having a pressure of between 50 and 300 bars advantageously being directed against the foamed slag vapor jet. The high-pressure water jet in that case enters a grinding or evaporation chamber as a counter-jet to the vapor jet at a high kinetic energy. The water jet evaporates on account of the enthalpy current of the slag droplets as well as the high-temperature driving vapor. The high kinetic energy of the high-pressure water is transmitted to the evaporated high-pressure water such that a vapor volume moved in a rapidly and directed manner is formed, which is directed against the particle-loaded high-temperature vapor propulsion jet at a high axially oriented speed. These two energetic potential fields mutually penetrate each other, causing the thus dissipated energy to directly result in particle disintegration, whereby the adjustment of the desired speed vector of the high-pressure water may be based on the preliminary pressure of the high-pressure water, the free length of the jet as well as the distance to the high-temperature vapor inlet for the further adjustment of the desired disintegration. In addition to the adjustability of the desired disintegration effect, i.e., the particle size to be achieved, it is, however, also feasible to optimize the disintegration efficiency by an appropriate selection of the distances, so that a high grinding efficiency may be adjusted, for instance, also by the appropriate adjustment of the preliminary pressure of the high-pressure water.

In the main, the formation of a foamed slag in the slag tundish, in addition to the adjustment of the desired slag composition, at the same time also allows for the formation of an accordingly high and highly pure hot gas volume which may be utilized energetically, for instance in a gas turbine, without requiring special exhaust gas purification means. As already mentioned, the slag basicity in the foamed slag may be adjusted to values of from 0.8 to 1.3 in a simple manner by the addition of CaO, Al_2O_3 and/or SiO_2.

The best results in terms of disintegration effect and desired grinding fineness could be observed where the volume weight of the foamed slag was adjusted to below 0.35 kg/dm^3, in particular approximately 0.28 kg/dm^3.

Surprisingly, it has been shown that foamed slags under super-atmospheric pressure exhibit an elevated stability. Advantageously, it is, therefore, proceeded in the context of the method according to the invention that the foamed slag is maintained under a pressure of between 3 and 7 bars. By such a formation, a pressure gradient is simultaneously generated at the spout of the foamed slag tundish, which causes the hot foamed slag to emerge at a high kinetic and thermal energy. The hot exhaust gas substantially has the same temperature as the foamed slag and is virtually free of dust and sulfur, thus being preferably suitable, for instance, as a propellant gas for a gas turbine, whereby a portion of the recovered mechanical energy may be used for air compressors to produce the bottom gas to be fed for the formation of the foamed slag.

In the main, the foamed slag generator in the slag tundish presents itself as a flameless combustion chamber of a gas turbine, by which relatively lumpy alternative fuels may be used directly and exploited in an economic manner.

The device according to the invention for carrying out this method essentially is characterized by a tundish into which a gas lance opens and/or in whose bottom tuyeres are arranged, that a foamed slag overflow and an outlet opening for slag are provided, that the tundish carries a pressure-proof lid to which a sluice is connected to charge solids and coal above the slag bath, and that a lance opens into the slag outlet opening to feed a carrier gas aimed to eject the foamed slag. Disintegration in this case is effected in a consecutively arranged grinding and/or evaporation chamber, to which end the configuration advantageously is devised such that a grinding and evaporation chamber is connected to the slag outlet opening, that a pressure water duct opens on the chamber side located opposite the slag outlet, and that a screening means

is connected to the grinding and evaporation chamber to discharge the disintegrated and granulated material. In addition to, or instead of, using high-pressure water it is basically also feasible to use reducing liquids or gases in the grinding and evaporation chamber, by which residual iron oxide remaining in the slag is reduced and rapid cooling is obtained, at the same time, due to the decomposition energy or cracking energy of hydrocarbons. The thus formed fine iron may be separated separately, for instance by magnetic separators. A substantial advantage of the formation of a foamed slag, in addition to the fact that relatively high temperatures may be provided within the foamed slag in a simple and controlled manner, also consists in that possible metallic slag iron is reliably burned so as to eliminate the basic risk of slag granulation explosions. Due to the high specific volumes of foamed slags, substantially larger slag outlet openings may be provided in the slag tundish, thus decisively minimizing the risk of obstruction or closing up by solids particles possibly entrained, for instance, as a result of a refractory material breakout. In view of the known devices, in which compact slags are ejected into a grinding or evaporation chamber, comparatively large clear diameters increased by a factor 10 to 100 may be provided as compared to known devices.

Advantageously, an exhaust gas duct is connected to the tundish, which exhaust gas duct is conducted via a gas turbine and/or a heat exchanger, thus further enhancing the energetic utilization and economic mode of operation.

In the following, the invention will be explained in more detail by way of an exemplary embodiment schematically illustrated in the drawing, of a device suitable for carrying out the method according to the invention. Therein, Fig. 1 is a schematic cross section through a slag tundish used to carry out the method according to the invention, and Fig. 2 depicts a schematic arrangement of a grinding and evaporation chamber following such a foamed slag generator.

In Fig. 1, 1 serves to denote a slag tundish whose bottom includes porous bottom blocks 2. Air and/or oxygen are introduced into a melt 4 via ducts 3 running through the porous bottom blocks 2, whereby a foamed slag is subsequently formed in the interior of the melt. The foamed slag reaches a slag outlet opening 6 via a foamed slag weir 5. Coaxial with said slag outlet opening 6 is provided the mouth of a lance 7, via which, for instance, high-pressure vapor may be pressed in so as to enable the foamed slag to be rapidly dispersed and disintegrated upon its emergence.

In order to increase the stability of the foamed slag, the slag tundish is designed to be closed, a lid 8 being provided. Solids and, in particular, CaO, Al_2O_3 as well as SiO_2 may be introduced directly into the foamed slag bath via a cellular wheel sluice 9 in order to adjust the basicity of the slag while, at the same time, safeguarding thorough mixing and a homogenous distribution due to great turbulences. The cellular wheel sluice 9 also may serve to introduce solid fuels such as, for instance, cheap coals in order to ensure the desired temperature of the foamed slag. Such lumpy coals are rapidly burned in the interior of the foamed slag by reaction with the oxygen contained in the pores at accordingly high temperatures, whereby highly pure exhaust gas may be drawn off via a duct 10 at a temperature substantially corresponding to the temperature of the slag. Slag temperatures of up to 2000°C and hence exhaust gas temperatures of the same order are readily feasible, such high temperatures, in the first place, forming in the interior of the foamed slag with a temperature gradient each being able to develop towards the edge of the foamed slag bath, whereby the refractory lining of the slag tundish 1 is accordingly saved. The slag tundish in this case may be maintained at a pressure of 3 to 7 bars, which substantially favors also the ejection of the foamed slag.

The foamed slag burner performance may be varied on a large scale. Thus, in particular with a view to the formation of accordingly highly pure exhaust gas streams having high temperatures, a suitable mode of operation as a flameless

burner may be chosen, from which the slag is each discharged after having reached the desired composition, and/or into which additional slag may be continuously introduced to form the desired foamed slag.

While the viscosity of conventional compact slags primarily decreases with increasing temperatures and increasing iron oxide portions, a foamed slag, which exhibits a structurally viscous flow behavior irrespective of its composition, has a substantially lower viscosity such that even slag compositions whose temperatures in the case of compact slag melts would have to be substantially higher may be sprayed without problems. At the same time, it is feasible to adjust nearly any desired high temperatures within the foamed slags from the start in an economic manner using cheap fuels, without this resulting in an increased wear of the refractory lining.

Fig. 2 depicts an advantageous disintegration device, which is arranged to follow a slag generator or slag tundish as illustrated in Fig. 1. The foamed slag feed is schematically indicated by chamber 11, into which a high-temperature vapor lance 12 opens. The foamed slag 13 enters a grinding and/or evaporation chamber via an opening 14 with a high-pressure water jet 15 being introduced in the opposite direction against the emerging jet via a high-pressure water lance 16. The high-pressure water lance 16 may be mounted so as to be displaceable in the sense of double arrow 17 so as to enable the adjustment of the desired parameters and, in particular, the spreading angle α substantially influencing the grinding degree and the grinding efficiency. In doing so, high-pressure water having a preliminary pressure of approximately 50 to 300 bars is used. High-temperature vapor may be used in a temperature range of between 200° and 1200°C and a pressure range of 5 to 15 bars. The spreading angle α entered in Fig. 2 also may be regarded as an evaporation gradient, the angle α becoming larger at a smaller pressure of the high-pressure water. The larger said angle α, the smaller the grinding efficiency and the coarser the ground material. In the main, it is feasible by simple settings to adjust both the grinding

efficiency and the reduction ratio to the respectively desired parameters, whereby the finely ground material may subsequently be drawn off via a screening device 18 and a duct 19.

As indicated in Fig. 1 in broken lines, air/oxygen may be blown into the foamed slag through a blowing lance 20, optionally along with carbon, in order to ensure the formation of the foamed slag and the desired foamed slag temperature. In those cases, no porous flushing blocks 2 need even be provided in the bottom.